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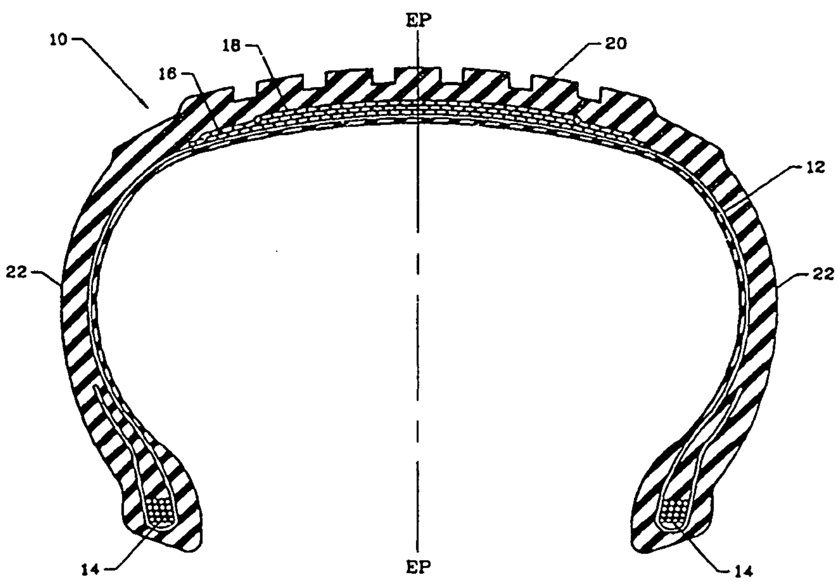
(54) Title: PEN REINFORCEMENT IN A TIRE OVERLAY



(57) Abstract

A pneumatic tire is made using a PEN overlay. The specially treated PEN cords used in the overlay show improvement in properties as compared to prior art PEN reinforcement. Tires made using the PEN overlay show improved noise properties, improved flatspotting, and improved wet handling properties, and substantially equivalent dry handling properties.

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PEN REINFORCEMENT IN A TIRE OVERLAY

Background of the Invention

The invention relates to passenger tires for use on paved roads and racing tires for road and off road use.

In the prior art it is known to use overlays in high performance tires to improve the speed rating and to improve the handling and cornering characteristics of the tire. Nylon is the preferred material for such overlays, but aramid overlays and PET (polyethylene terephthalate) overlays and overlays of other materials have been tested in tires. Aramid overlays are generally considered to cause the tire ride to be harsh and to make the tire too noisy, and polyester is difficult to work with in such applications. Although nylon overlays work fairly well, the nylon material can sometimes cause flatspotting in tires. It is a continuing goal in the art to improve overall tire properties by testing new materials and new tire constructions.

PEN (polyethylene naphthalate) has apparently been tried as a cap ply material and as a tire carcass reinforcement material as early as the 1970's. PEN has never previously been used, as far as applicant has been able to ascertain, as an overlay material in tires.

Summary of the Invention

A pneumatic tire for use on paved roads has an aspect ratio of 0.2 to 0.8 and a width of 175 mm to 340 mm and comprises a pair of parallel annular beads, 1 to 2 carcass plies wrapped around the beads, a belt package disposed radially outward of the 1 to 2 carcass plies in a crown area of the tire, an overlay

having a width coinciding substantially with the width of the belt package, a tread disposed radially outward of the overlay, and a sidewall disposed between the tread and the beads. The overlay comprises PEN reinforcement filaments or cords embedded in an elastomer. The overlay can be spirally wound radially outward of said belt package and may comprise a continuous strip of elastomeric reinforcing tape having a width of 1/2 inch to 1-1/2 inches and 4 to 24 parallel reinforcing filaments or cords embedded therein. Alternatively, the overlay may comprise a single ply.

The PEN reinforcement cords used in the invention may have a linear density of 240 dTex to 2200 dTex. As used herein, dTex is short for decitex. Cords made using the yarns may have a twist multiplier of 5 to 10.

A method is provided for preparing reinforcement cords used in the tire of the invention wherein PEN cord is treated by the steps of (a) twisting cords to have a twist multiplier of 5-10, (b) dipping the cords in a first adhesive dip, (c) passing the cords through a drying zone, (d) applying a tension of 1500-3200 lbs on the cords, (e) dipping the cords in a second adhesive dip at a tension of 1500-3200 lbs, (f) maintaining the 1500-3200 lbs tension through a set point at a temperature sufficient and a time sufficient to bond the adhesive to the cord, and (g) winding the cord on a storage roll.

Brief Description of the Drawings

Fig. 1 illustrates a cross section of a tire having an overlay.

Fig. 2 illustrates a top, cut-away view of a single-ply overlay in a tire

Fig. 3 illustrates a cross-section view of a spiral overlay in a tire

Fig. 4 illustrates an apparatus used to treat the cords of the invention.

Detailed Description of the Invention

With reference now to Fig. 1, a tire 10 of the invention comprises at least one carcass ply 12 wrapped around a pair of parallel annular beads 14, belt ply reinforcement 16 disposed over carcass ply 12 in a crown area of the tire 10, overlay 18 disposed radially outward of the belt reinforcement, tread 20 disposed radially outward of the overlay, and sidewalls 22 disposed between the tread 20 and the beads 14.

The tire may have one to four carcass plies and one to four belt plies, preferably one or two carcass plies and preferably two or four belt plies which are reinforced with parallel reinforcing cords comprising, for example, polyamides, aromatic polyamides, polyesters, cellulosics, steel, fiberglass, carbon fibers, or mixtures thereof.

Overlay 18 may be laid up in a single ply (Fig. 2) or as a spiral wrap (Fig. 3).

It is believed that yarn of 240 dTex (decitex) to 2200 dTex can be used according to the invention, depending on the size of the tires constructed and their use, and in general, yarns of 550 dTex to 1100 dTex will most often be used.

With reference to Fig. 2, when single ply over lay 18a is used in a tire, it may be applied to the belt structure of the tire using an overlap splice, a butt splice, or to distribute the stresses caused by the splice, using an angled splice.

With reference to Fig. 3, when a spiral layup 18b is used to construct a tire, any of the conventional spiral layups known to those skilled in the art can be used. In the illustrated embodiment a K+990 spiral overlay, which is conventional for Invicta tires was used. A K+990 spiral overlay comprises three turns of 25mm wide overlay strip offset 3mm on the shoulders of the tire and two turns of overlay strip offset 12.5mm through the center of the tire.

According to the present invention overlay 18 comprises PEN reinforcing cords encased in a conventional ply elastomer.

The present inventors have found that PEN cords show heightened process sensitivity to twisting and treating conditions. By increasing the tension on the cords during dipping in an adhesive (typically an RFL latex adhesive) when the proper twist multipliers are used, the treated cord tenacity increases. In addition, more uniform (i.e. more reproducible) PEN treated cord tensile properties are obtained.

The treatment of the cord makes it possible to minimize the amount of PEN reinforcement needed to meet design requirements in an overlay, which may reduce material costs, tire weight, and provide improved tire performance, e.g. reduced rolling resistance and tire uniformity.

In the illustrated embodiment, a PEN yarn available from Allied Signal designated A701 (poly(ethylene-2,6-naphthalene dicarboxylate)) was

treated by The Goodyear Tire & Rubber Company using special tensions and twisting.

The PEN yarn used in the tires of the example was treated at Goodyear's Decatur, Illinois production facility. Since only a small test run was possible, it was decided to use a cord construction that could be used in a tire carcass or a tire overlay. Although the cord was not optimized for either purpose, it was believed that the cord could be used to show the utility of PEN reinforcement in both tire applications.

The test cord construction chosen was 1100 dTex/1/2 cords having a twist of 472Z x 472S where the twist is given in turns per meter (tpm).

As is known to those skilled in the art, the cords are generally woven into a textile fabric for treatment and the weft cords of the textile fabric are broken or otherwise removed before the cords are calandered into a ply.

Figure 4 shows a schematic plan view of equipment which can be used for preparing the cords used in the tires of the invention. The equipment includes a pay-off 41 for unwinding a roll of greige textile fabric 40, a number of guiding rolls 42, a festoon 43 followed by a set of pull rolls 44. Pull rolls 48 pull the textile fabric from pull rolls 44 and the textile fabric 40 enters a dipping unit 45 and thereafter a drying tower 46. The dipping unit 45 contains a coating solution, which ordinarily is an adhesive. Such adhesives are e.g. described in the book "Mechanics of Pneumatic Tires", US department of transportation, US Government Printing Office, 1982; pp. 92-93. The textile fabric migrates through the drying tower in 30 to 90 seconds and is exposed, in a

controlled atmosphere containing hot air, to a temperature of 130-170°C.

From pull rolls 48, the textile fabric is pulled by pull rolls 48a into high temperature oven 47 wherein the temperature is set at 220-265°C. Staying times for the cords of the invention at the indicated temperature is 30 to 120 seconds.

Pull rolls 48b thereafter pull the textile fabric through a second dipping unit 49, a second drying unit 50 and a second high temperature oven 51. The dipping unit 49 again contains an adhesive. The textile fabric crosses the drying tower 50 in 30 to 90 seconds and is exposed, in a controlled atmosphere containing hot air, to a temperature of 100-170°C. The second high temperature oven 51 operates at the same temperature as the first high temperature oven 47, preferably 220-265°C. This temperature provides a set point that permits the adhesive to react with the textile fabric. The high temperature oven 51 is followed by pull rolls 48b, festoon 53 and wind-up unit 54.

As the textile fabric 40 is pulled lengthwise from the pay-off 41, through the festoons 43, 53, the dipping units 45, 49, the drying towers 46, 50 and the high temperature ovens 47, 51, the various tensions provided by pull rolls 48a, and especially pull rolls 48b, allow a precise tuning of the tension applied to the cords during the different treatment steps. This together with the temperatures used in the set point ovens 47, and more especially oven 51, are primarily responsible for the properties demonstrated by the cords of the invention.

In the illustrated embodiment, the twisted cords were dipped twice in an RFL epoxy adhesive. In the first dip 45, the cords were subjected to a minimal

tension to permit good penetration of the adhesive into the cords. After dipping the cords were passed through vacuum, by radiant heaters and dryers 46 to reduce the fluidity of the adhesive, and onto the first major pull roll 48. The first pull roll 48 is the source of the tension on the cord up to this point. After passing the first pull roll 48, the tensions applied by the second pull roll 48a, about 1500-3200 lbs (in the illustrated embodiment 2000-2600 lbs) act on the cord as the cord passes through the set point in oven 47. Thereafter, a third pull roll 48b applies a tension of 1500-3200 lbs (in the illustrated embodiment 1800-2400 lbs) as the cord enters the second adhesive dip 49 and continues through vacuum, radiant heaters, drying ovens and cooling chambers 50 and through the second set point oven 51 and to the third pull roll 48b. Thereafter, the windup roll 54 pulls the cord, using minimal tension, thereon for storage.

Set temperatures in ovens 47 and 51 may be 220 to 265° C depending on the adhesive used. Residence times may vary from 30 seconds to 120 seconds depending on the temperature and the adhesive used. The drying zone primarily reduces the fluidity of the adhesive so the adhesive sticks to the cord as it is transported by the vacuum and over the rolls and the temperature in the drying zone (usually about 100 to 170° C) is sufficient for this purpose. In the illustrated embodiment where an RFL epoxy adhesive was used, tensions in the first drying zone 46 were maintained at 1000 lbs for 60 seconds residence at 140° C.

Those skilled in the art will recognize that residence times and temperatures may be varied within reasonable limits, and that the tension and

temperature in the first drying zone 46 is apparently not critical to final cord properties.

Illustrative cords made to the inventors' specifications and the cords' properties are described in the table below.

The illustrated 1100 dTex/1/2 PEN filaments/cords show a T-Shrinkage of 1.44% a LASE @5% of 74N, a break strength of 148N, and a Dynamic Flex Fatigue (1" spindle) of 92% Ret BS (Retained Break Strength). LASE is short for Load at Specified Elongation.

Table 1

Property	PEN Cord Constructions			
	550/1/2 551Zx 551S	1100/1/2 472Zx 472S	1100/1/3 394Zx 394S	1670/1/2 354Zx 354S
T-Shrinkage, %	1.76	1.44	3.2	1.0
LASE @5%,N	45	74	99	100
Break Strength, N	74	148	252	200
Dynamic Flex Fatigue (1" spindle) % Ret BS	96	92	94	96

The cord linear densities in the table are given in dTex and the twists (Z,S) are given in turns per meter. As is conventional in the art, Z denotes a left hand twist and S denotes a right hand twist, and the first number in the twist part of the construction is the twist of the yarn (sometimes referred to as ply) and the second number is the twist of the cord (sometimes referred to as the cable twist).

The T-Shrinkage Test is most relevant when an overlay ply is used since it provides an estimation of

how much the ply will slip at the overlap splice due to shrinkage of the overlay ply, which may be important to the uniformity of the tire.

The LASE relates to the modulus of the material and is indicative of expected high speed performance. Generally, the higher the LASE, the better the high speed performance.

Reinforcement cords used in a tire can be chosen for their material properties or their cost, depending on their use in a tire and the strength of reinforcement needed in a particular tire application. The cost of reinforcement material can sometimes be reduced by reducing conversion (twisting time) costs, for example by reducing the twist of the yarn or cords. It is believed that tires of the invention will have suitable properties when the cord has a twist multiplier (TM) of 5-10, preferably 6-9. The TM is defined by the formula

$$TM = ((tpm \times 0.0254) \times (dTex/1.111))/73$$

where dTex represents the linear density of the bulk greige yarn.

The 1100 dTex/1/2 cords illustrated which were treated at high tensions are close in size to 940 dTex nylon used in overlay applications, and the 472Z x 472S twist is typical for conventional PET (polyethylene terephthalate) reinforcement cords.

Yarn twists and cable twists can be the same or different and can be from 118 tpm to 630 tpm depending on the linear density or the dTex of the yarn, and the limitation that the cord twist multiplier be 5-10.

The twists used on the illustrated cords are typical for PET and have not been optimized for PEN.

When an overlay reinforced with PEN filaments or cords described is used in the construction of a high performance tire, such tires have shown an improvement

in noise properties, an improvement in subjective handling, an improvement in wet handling, and reduced flatspotting as compared to tires of similar construction made with a conventional nylon overlay. High speed durability of the tires made with the PEN reinforced overlay is down slightly as compared to the tire made with the nylon overlay while all other properties are substantially equal.

The invention is further illustrated with reference to the following examples.

EXAMPLE

To characterize the properties of the tires of the invention, four tire constructions were made with various combinations of PET (polyethylene terepthalate) and PEN (poyethylene napthalate) carcass plies with nylon and PEN overlays. Conventional cut steel belts were used in all the tire constructions of the example. The conventional tire construction using a PET cord reinforced carcass ply with a nylon cord reinforced overlay was used as a control. To characterize PEN as a carcass ply material, an experimental tire was made using a PEN reinforced carcass ply and a conventional nylon overlay. To characterize PEN as an overlay material, two additional constructions were built using a PEN reinforced overlay with a PEN reinforced carcass ply and a conventional PET reinforced carcass ply.

The same 1100 dTex/1/2 472Z x 472S PEN cords were used as reinforcement cord for the plies and the overlays in the example.

Tires used in the evaluation were size P215/60R16, using Invicta GA mold and component specifications, except as modified as described in the examples.

The tires exhibited the following properties in tire testing.

TABLE 2

ply material	PET	PEN	PET	PEN
overlay material	nylon	nylon	PEN	PEN
<u>force & moment</u>				
corn. coeff.		=	=	=
align. torque		+	=	+
<u>static measurement</u>				
static load		=	=	=
OD	26.2	26.18	26.20	26.17
OW	8.79	8.88	8.72	8.86
DOT high speed durability		+1	-1	=
DOT extended endurance		=	=	=
DOT plunger energy	100	100	104	103
<u>dynamic testing</u>				
subjective noise		-	+	=
subjective harshness		-	-	-
subjective handling		=	+	+
wet handling(time)	53.15	53.00	52.62	52.55
dry handling(time)	32.39	32.51	32.28	32.11

In the table, force & moment refers to standard tests where the lateral forces exhibited by a tire are measured on force wheels in the laboratory as a prediction of handling performance.

The OD and OW are diameter and width measurements of the tire taken to assure there are not significant differences between the experimental tire builds.

DOT refers to the Department of Transportation, and the tests identified as DOT are standard DOT tests.

The dynamic testing refers to subjective comments by test drivers.

In outdoor resiliometer testing, all tires stop/finished with no failures.

In accelerated tire endurance testing, all experimental constructions stop/finished, but there was one control failure.

Runout was comparable to the control for all constructions.

Flatspotting was significantly less in the constructions using the PEN overlay.

Driver analysis and comments

Subjective noise: PEN reduces tread noise, breaking growl, and road roar...especially when used as an overlay.

Subjective harshness: PEN tends to have less damping characteristics as ply and as overlay.

Subjective handling: response, linearity and gain characteristics tend to be sharper for PEN ... especially in overlay constructions.

CONCLUSIONS

There were no durability issues seen with PEN as a ply, overlay, or ply/overlay. PEN as a ply does not appear to offer any tire performance improvements over PET. PEN as an overlay offers potential for improved flatspotting and vehicle handling.

While the invention has been specifically illustrated and described, those skilled in the art will recognize that the invention can be variously modified and practiced. The limits of the invention are defined by the scope of the following claims.

WHAT IS CLAIMED IS:

1. A pneumatic tire having an aspect ratio of 0.2 to 0.8 and a width of 175 mm to 340 mm and comprising a pair of parallel annular beads, 1 to 2 carcass plies wrapped around said beads, a belt package disposed radially outward of said 1 to 2 carcass plies in a crown area of said tire, and overlay having a width coinciding substantially with the width of said belt package, a tread disposed radially outward of said overlay, and a sidewall disposed between said tread and said beads, wherein said overlay comprises PEN reinforcement filaments or cords embedded in an elastomer.

2. The pneumatic tire of claim 1 wherein the PEN reinforcement filaments have a density of 240 dTex to 2200 dTex.

3. The pneumatic tire of claim 1 wherein said overlay is spirally wound radially outward of said belt package and comprises a continuous strip of elastomeric reinforcing tape having a width of 1/2 inch to 1-1/2 inches and 4 to 24 parallel reinforcing filaments or cords embedded therein.

4. The pneumatic tire of claim 1 wherein said PEN reinforcement cords have a twist multiplier of 5 to 10.

5. The pneumatic tire of claim 1 wherein said PEN reinforcement are 1100 dTex/1/2 cords having a twist of 472Z x 472S.

6. The pneumatic tire of claim 1 wherein PEN filaments/cords show a T-Shrinkage of 1.44% a LASE @5% of 74N, a break strength of 148N, and a Dynamic Flex Fatigue (1" spindle) of 92% Ret BS.

7. The pneumatic tire of claim 3 wherein the spiral overlay comprises a K+990 layup.

8. The pneumatic tire of claim 1 wherein said at least one carcass ply is reinforced with parallel reinforcing cords comprising polyamide, aromatic polyamides, polyester, cellulosics, steel, fiberglass, carbon fibers, or mixtures thereof.

9. The pneumatic tire of claim 1 wherein the overlay is a single ply overlay.

10. The pneumatic tire of claim 1 wherein the reinforcement cords have ply twists and cable twists that are the same or different and comprise 118 tpm to 630 tpm.

11. A method of treating a PEN cord comprising the steps of

(a) twisting cords to have a twist multiplier of 5-10,

(b) dipping said cords in a first adhesive dip,

(c) passing the cords through a drying zone,

(d) applying a tension of 1500-2800 lbs on the cords and passing the cords through a first set point at a temperature sufficient and a time sufficient to bond the adhesive to the cord,

(e) dipping the cords in a second adhesive dip at a tension of 1500-2800 lbs,

(f) maintaining the 1500-2800 lbs tension through a second set point at a temperature sufficient and a time sufficient to bond the adhesive to the cord, and

(g) winding the cord on a storage roll.

12. The method of claim 11 comprising the further step of providing a residence time of 30-60 seconds at a temperature of 230-280° C in said first and second set points.

13. The method of claim 11 wherein the tension in said second dip is maintained at 2000-2600 lbs.

14. The method of claim 11 wherein the tension in said drying zone is maintained at 1000 lbs for a time sufficient to reduce the fluidity of the adhesive.

15. A PEN cord made according to the method of claim 11.

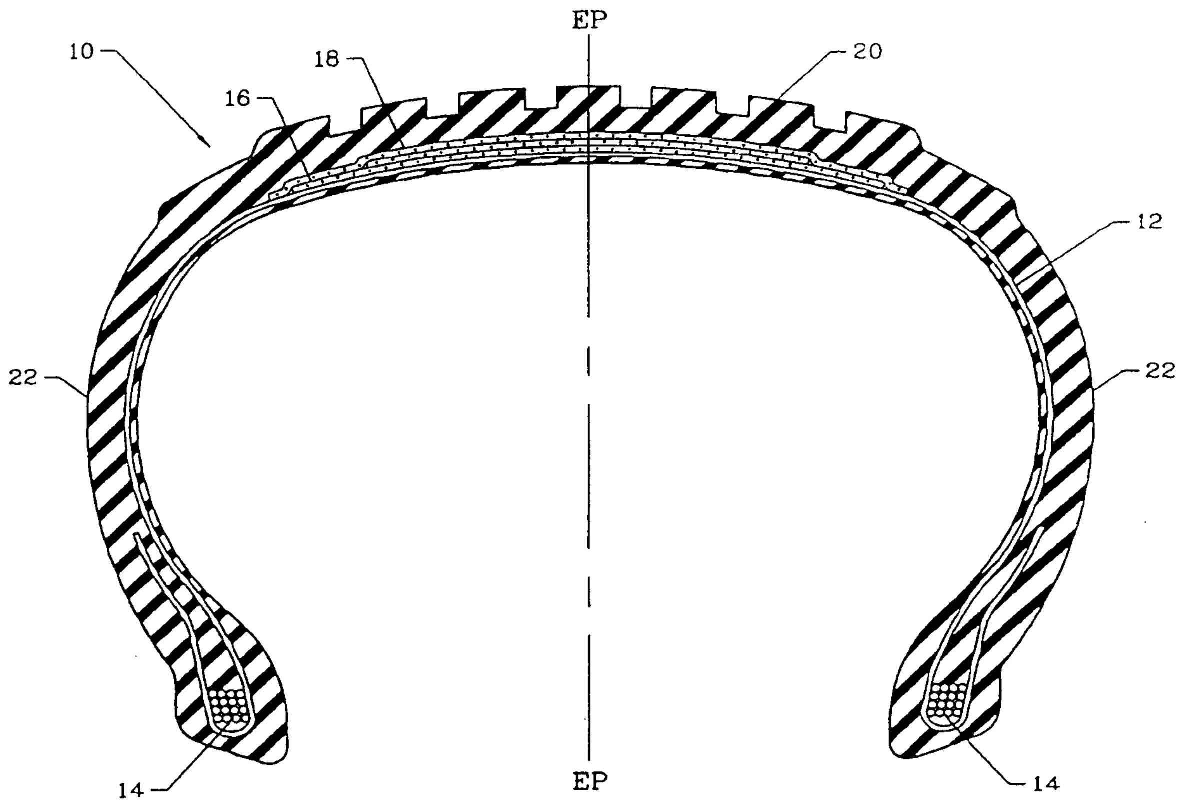


FIG.1

FIG-2

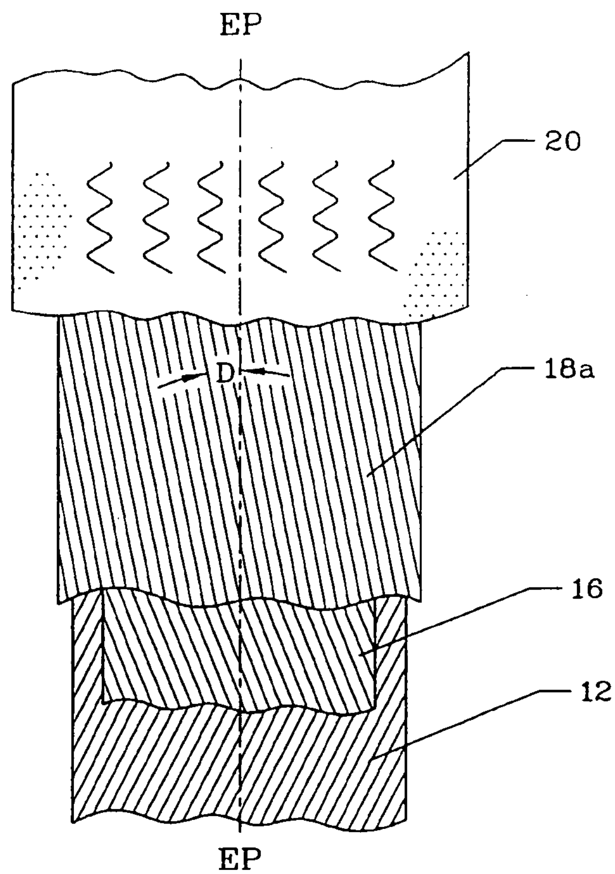
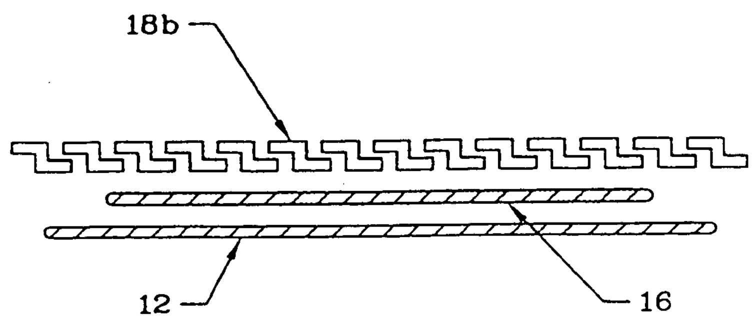


FIG-3



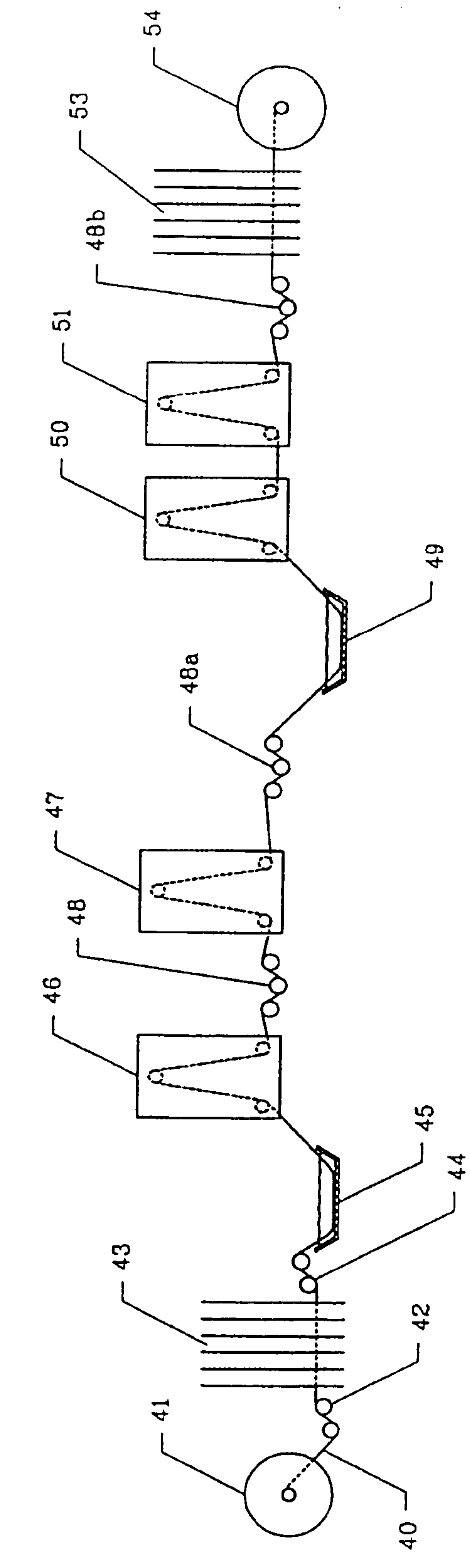


FIG. 4

INTERNATIONAL SEARCH REPORT

Int. onal Application No
PCT/US 97/06757

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 B60C9/22 B60C9/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 B60C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 749 854 A (BRIDGESTONE CORP) 27 December 1996 see claims; table 1	1-10
Y	see page 6, line 20 - line 39 ---	11-15
X	EP 0 715 971 A (BRIDGESTONE CORP) 12 June 1996 see claim 2; example 14; table 1 ---	1-4
X	PATENT ABSTRACTS OF JAPAN vol. 097, no. 006, 30 June 1997 & JP 09 030210 A (BRIDGESTONE CORP), 4 February 1997, see abstract --- -/--	1,2,4

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
8 December 1997	16/12/1997
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Authorized officer Baradat, J-L

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INTERNATIONAL SEARCH REPORT

Int. ional Application No
PCT/US 97/06757

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	EP 0 458 647 A (HOECHST CELANESE CORP) 27 November 1991 see page 3, line 1 - line 9; examples 13,23 ---	11-15
A	RIM P R: "THE HIGH PERFORMANCE PROPERTIES OF PEN FIBRES IN TYRE REINFORCEMENT" KAUTSCHUK UND GUMMI - KUNSTSTOFFE, vol. 49, no. 6, 1 June 1996, pages 418-423, XP000598250 ---	1,11
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